

Nautilus Retrospective: 1972-2014



Nautilus pompilius, Fiji 1976



Fiji: 1972 - 1975



From 1972 - 1975 I and others conducted surveys throughout Fiji for the University of the South Pacific on mollusks and other marine life. These efforts yielded no living *Nautilus* nor had anyone at that time ever seen a living *Nautilus*. Trapping methods for *Nautilus* were unknown to us.



L'AUTEUR

René CATALA, originaire des Vosges, s'intéresse, dès le jeune âge, aux sciences naturelles et plus spécialement à l'entomologie.

A Madagascar, où il passe dix-sept années, ses activités se partagent entre la mise en valeur de plantations de café, de poivre, de vanille et la création d'un laboratoire installé en lisière de la forêt vierge. C'est là qu'il entreprend l'étude des variations expérimentales de l'un des plus beaux papillons du monde, l'*Urania*. Ces recherches se concrétisent par un important ouvrage magnifiquement illustré de planches en couleurs, publié en 1940 par le Muséum National d'Histoire Naturelle de Paris avec la contribution de l'Académie des Sciences et du Centre National de la Recherche Scientifique.

Mais c'est en 1936 que, lors d'une escale à Nossi-Bé, île du Nord-Ouest Malgache, René CATALA avait découvert la féerie des récifs coralliens. Toute l'orientation de sa vie de biologiste devait s'en trouver changée avec cette idée-force : créer un centre de recherches scientifiques à proximité de récifs d'une richesse exceptionnelle en organismes marins tels qu'il s'en trouve en Nouvelle-Calédonie.

d'espèces répandues dans l'Océan Indien et dans l'aire Indo-Pacifique. Elles appartiennent toutes au genre *nautilus*. Le nautilé de Nouvelle-Calédonie est *Nautilus macromphalus*.

Tout le monde a vu des coquilles... vides de Nautilés, sur les plages des îlots du lagon et celles de la grande terre où elles viennent s'échouer après avoir flotté longtemps en surface grâce à l'air resté emprisonné dans les chambres compartimentées.

En effet, si l'on effectue une coupe de cette coquille (qui est une spirale régulière, roulée sur le même plan) on voit qu'elle est divisée, à l'intérieur, en nombreuses loges formées par des cloisons transverses, concaves vers l'avant et traversées en leur milieu par un orifice qui correspond au passage du syphon.



Fig. 26. Le NAUTILE.

Au fur et à mesure que la bête grandit, elle avance dans sa coquille, obturant derrière elle, par une cloison de nacre, la dernière chambre occupée, et ainsi de suite jusqu'au moment où, sa croissance étant terminée, elle vient habiter la grande chambre extérieure.

A la différence des autres céphalopodes, les nautilés ne possèdent pas de poche à encre.

L'animal est pourvu d'un syphon. A l'aide de cet organe, il refoule l'eau qui a servi à sa respiration et nage par un effet de réaction contre le liquide ambiant. Ce système de propulsion à réaction, nous le retrouvons chez les pieuvres, les calmars et les seiches. Mais, chez le

nautilé, la partie externe du syphon est formée de deux lobes qui peuvent, en se joignant, faire office de valve. L'orifice du syphon (on pourrait dire... la « tuyère ») a, de plus, la curieuse faculté de se mouvoir dans tous les sens et par conséquent d'aider la bête à modifier l'orientation de sa navigation.

Celle-ci se fait le plus souvent dans le sens dû à l'éjection de l'eau, autrement dit, l'animal navigue surtout en arrière.

Beaucoup de personnes font une confusion entre le nautilé et l'argonaute. C'est ce dernier seulement qui se voit en haute mer dressant au-dessus de l'eau ses bras assez longs pour que leur réunion ait pu faire croire qu'il s'en servait comme d'une voile.

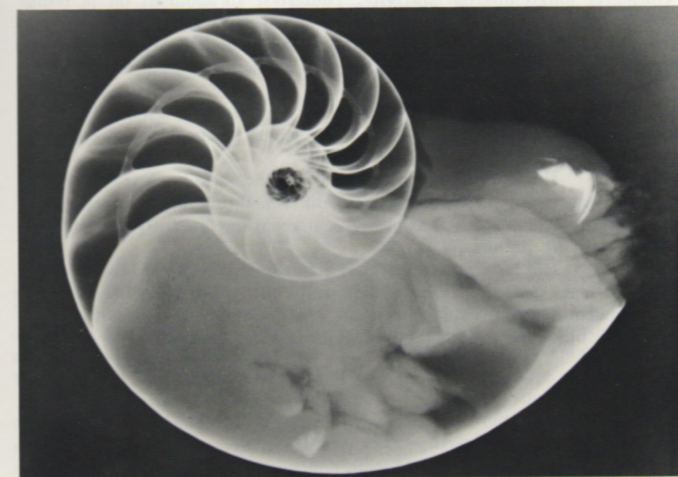


Fig. 27. Radiographie d'un Nautilé vivant.

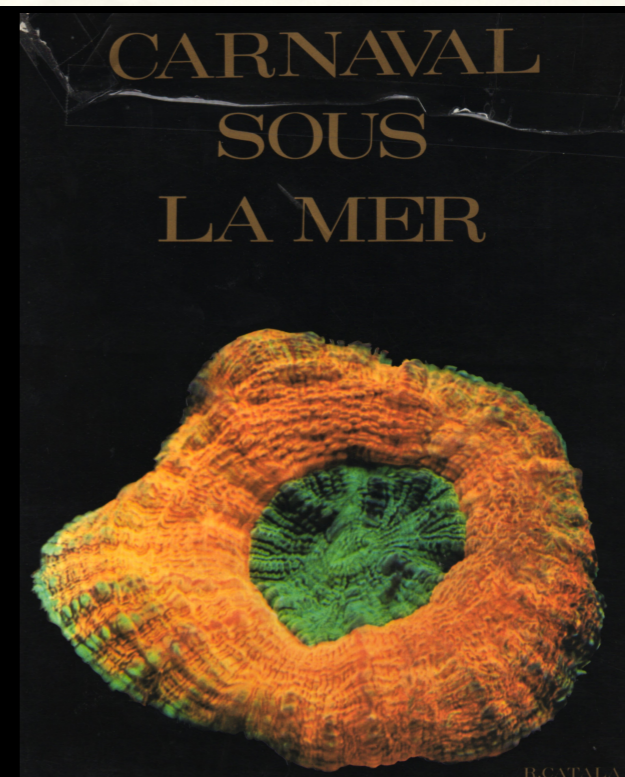
Comme le montrent les deux photographies (fig. 26 et pl. XXIII, fig. 3) (les premières faites d'un individu vivant) (1) le nautilé, lui, n'a que des tentacules très courts que l'on aperçoit en dessous d'une sorte de capuchon triangulaire et charnu.

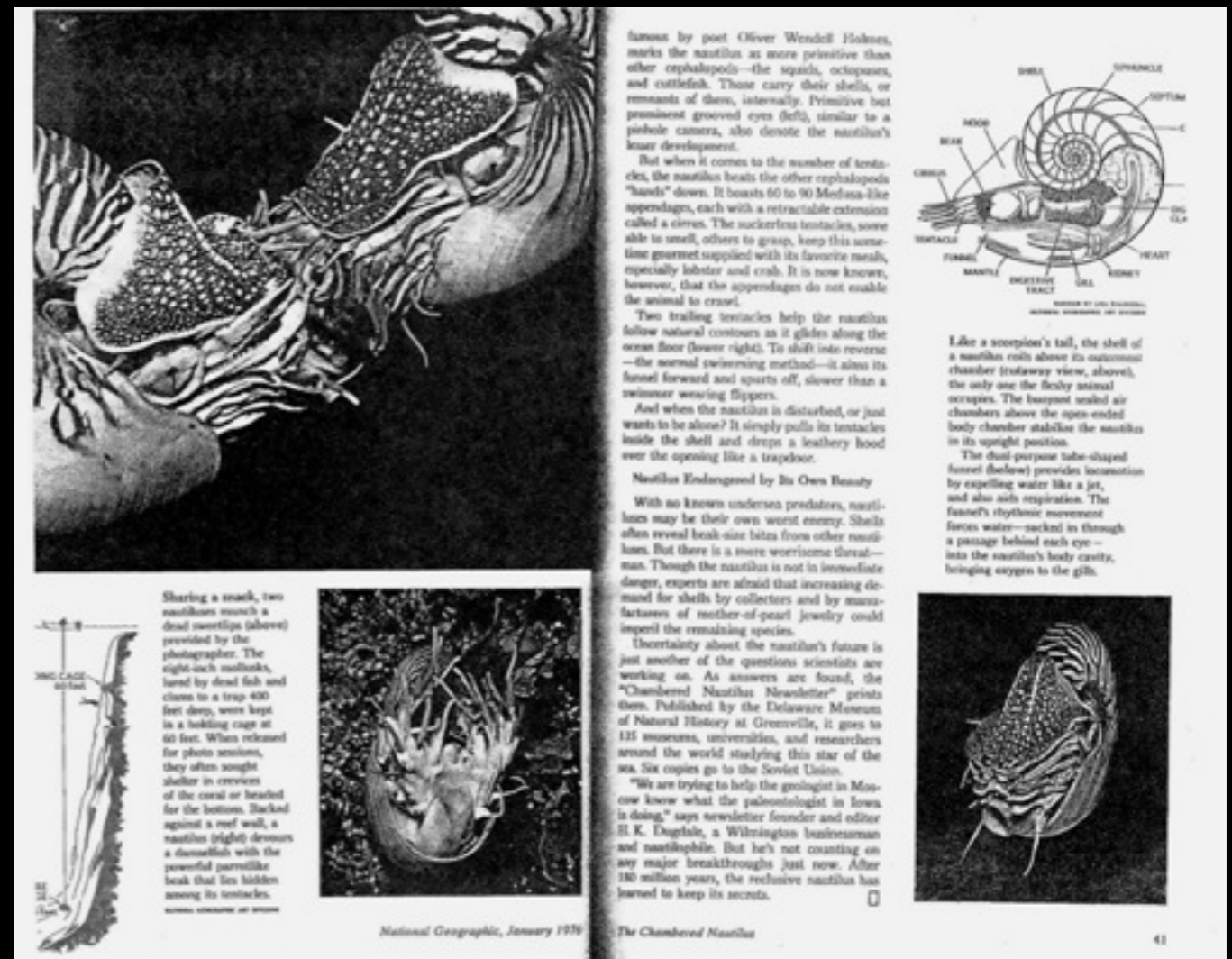
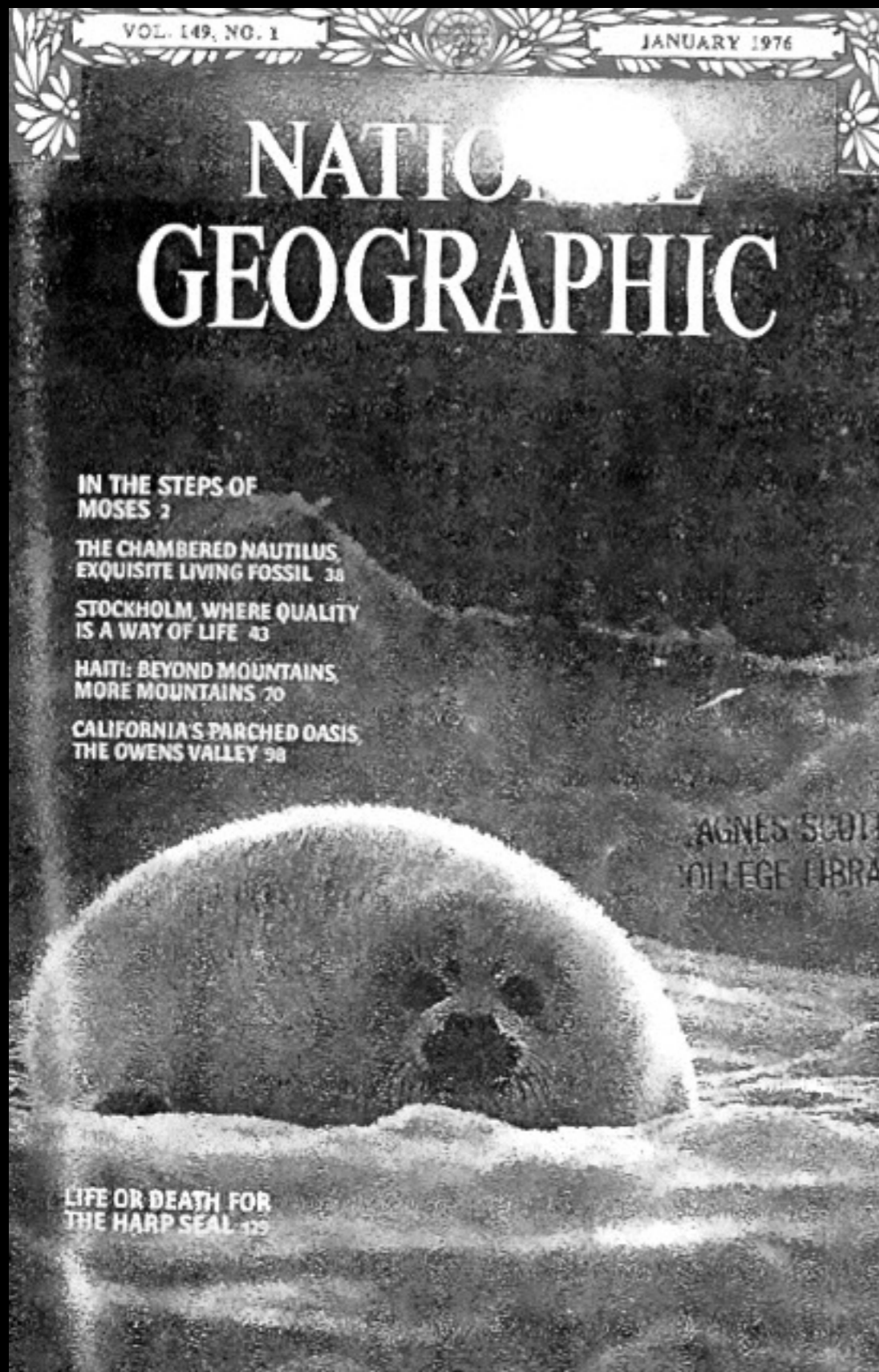
Les gros yeux du nautilé sont beaucoup plus simples que ceux des autres céphalopodes. Ils sont attachés par un pédoncule et doués d'une certaine mobilité. Mais on peut dire qu'ils « voient mal ».

(1) De quelques séquences en couleurs tournées par nous à l'aquarium, les « Actualités Françaises », sous les auspices de leur charmant directeur, Monsieur Héliard, ont tiré un très joli court métrage de nautilés évoluant en groupe, film qui a été projeté en Europe en 1959, et au 10^e Congrès des Sciences du Pacifique à Honolulu en 1961.

1964

Noumea Aquarium in New Caledonia had been displaying *Nautilus* since 1958 but most had been caught in shallow water at night (?). In Fiji, they do not swim into very shallow water at night.





Doug Faulkner's 1976 article in National Geographic was the inspiration to try trapping *Nautilus* in Fiji



Fiji 1976: Peter Ward

By coincidence, Peter Ward was also trapping *Nautilus* in Fiji in 1976 working with the Ministry of Fisheries





1976: Peter Ward with Fiji *Nautilus*



Fiji 1976: University of the South Pacific

Photo of our simple chicken wire and fence-wire trap, funnels at each end. This trap design is easily constructed in an hour from pieces that can be pre-fabricated



Fiji 1976: Suva Harbour

Colleague Webber Booth at *Nautilus* trap buoy.
Trap set at 800' outside Suva Harbour



Lifting trap by running trap-line through handle on empty barrel and motoring slowly, then quickly pulling in slack on line when boat stops

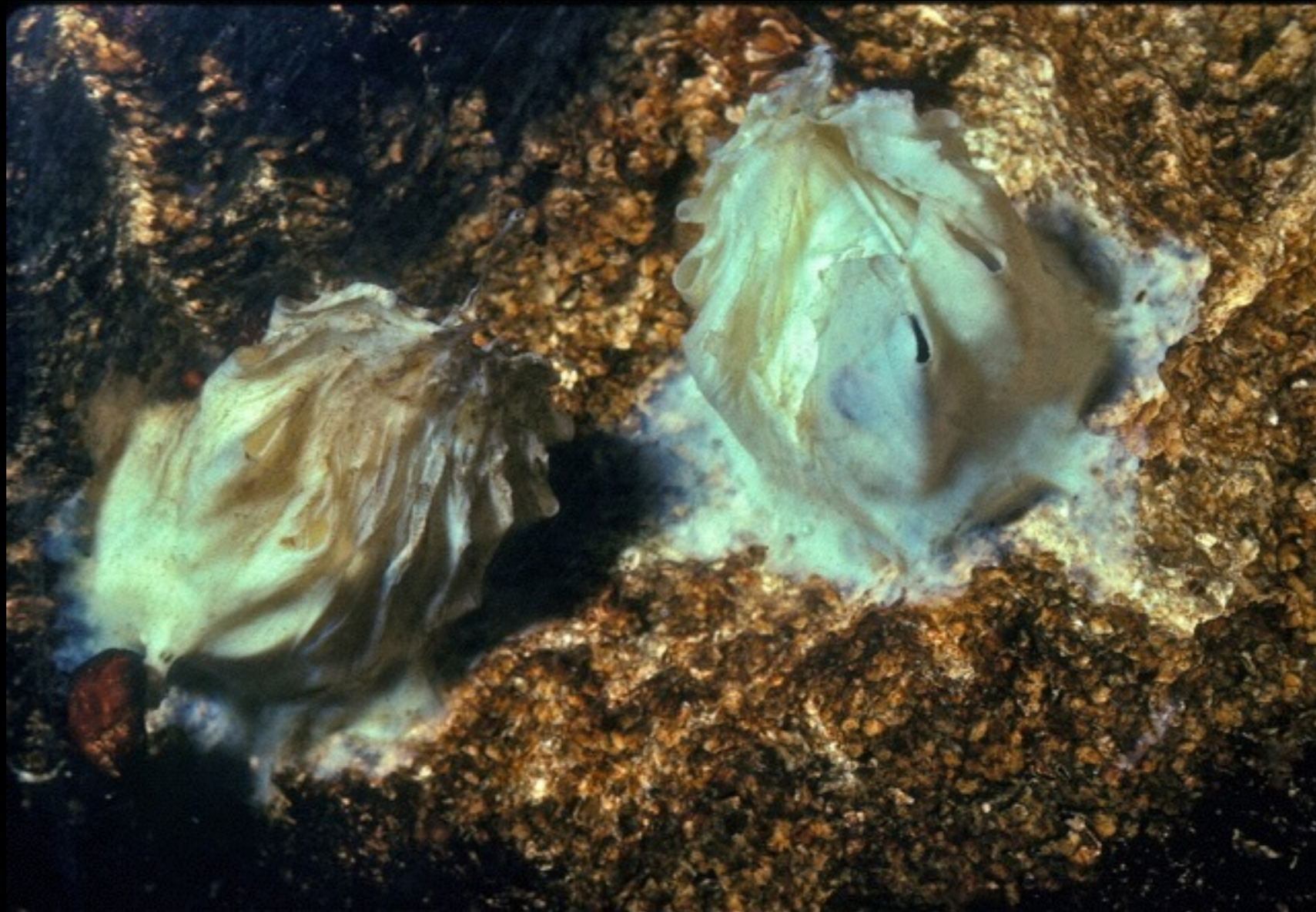


Fiji 1976: Our first (and only) trap set yielded 13 *Nautilus* from Suva Harbour





1976: All 13 Fiji *Nautilus pompilius* survived shipment to the Waikiki Aquarium, Honolulu, and became the first successful exhibit of living *Nautilus* outside of New Caledonia



Waikiki Aquarium 1976: *N. pompilius* eggs

The Fiji *Nautilus* produced eggs within a month after arrival but they failed to develop



Palau, 1977

Mike deGruy joined the Waikiki Aquarium in 1977 and we organized a *Nautilus* collecting trip to Palau



Palauan *Nautilus* were much larger than those in Fiji and trap yields were also much greater. We only kept about 12 animals, releasing the rest. (Horace “Dug” Dugdale is just outside the picture on the left)



A max-min thermometer attached to the Palau trap gave us our first understanding that temperatures at trap-depths could be as cold as 10-degrees C. With this new information, we set up a chilling system for *Nautilus* at the Waikiki Aquarium



Palau 1977:

Bruce Saunders was also in Palau beginning his pioneering research on *Nautilus*



Palau 1977: Claude Spinoso, Mike deGruy & Bruce Saunders

Palau: 1978

To improve husbandry methods for *Nautilus*, we had to learn more about its behavior and biology. The accompanying shot is a freeze-frame from a super-8 movie from 1978 that documented the first effort to successfully track one *Nautilus* using a transmitter



Mike deGruy

Observations on the Vertical Distribution of the Chambered *Nautilus* in the Palau Islands

BRUCE A. CARLSON⁵ and MIKE V. DEGRUY⁶

Field observations on the cephalopod mollusk *Nautilus* sp. (cf. *repertus*) from the Palau Islands indicate that it is one of the dominant organisms in deep-reef environments. Fifty-one animals were collected in

July 1977 and 74 more were collected in February 1978. Depths of capture ranged from about 200 to 400 m, with temperatures varying from 7° to 10°C. Males were much more common than females in trap collections and only three juveniles were collected. One *Nautilus* was tagged with an ultrasonic transmitter and its vertical and horizontal movements were monitored from the surface using a unidirectional hydrophone over a 7-hr period.

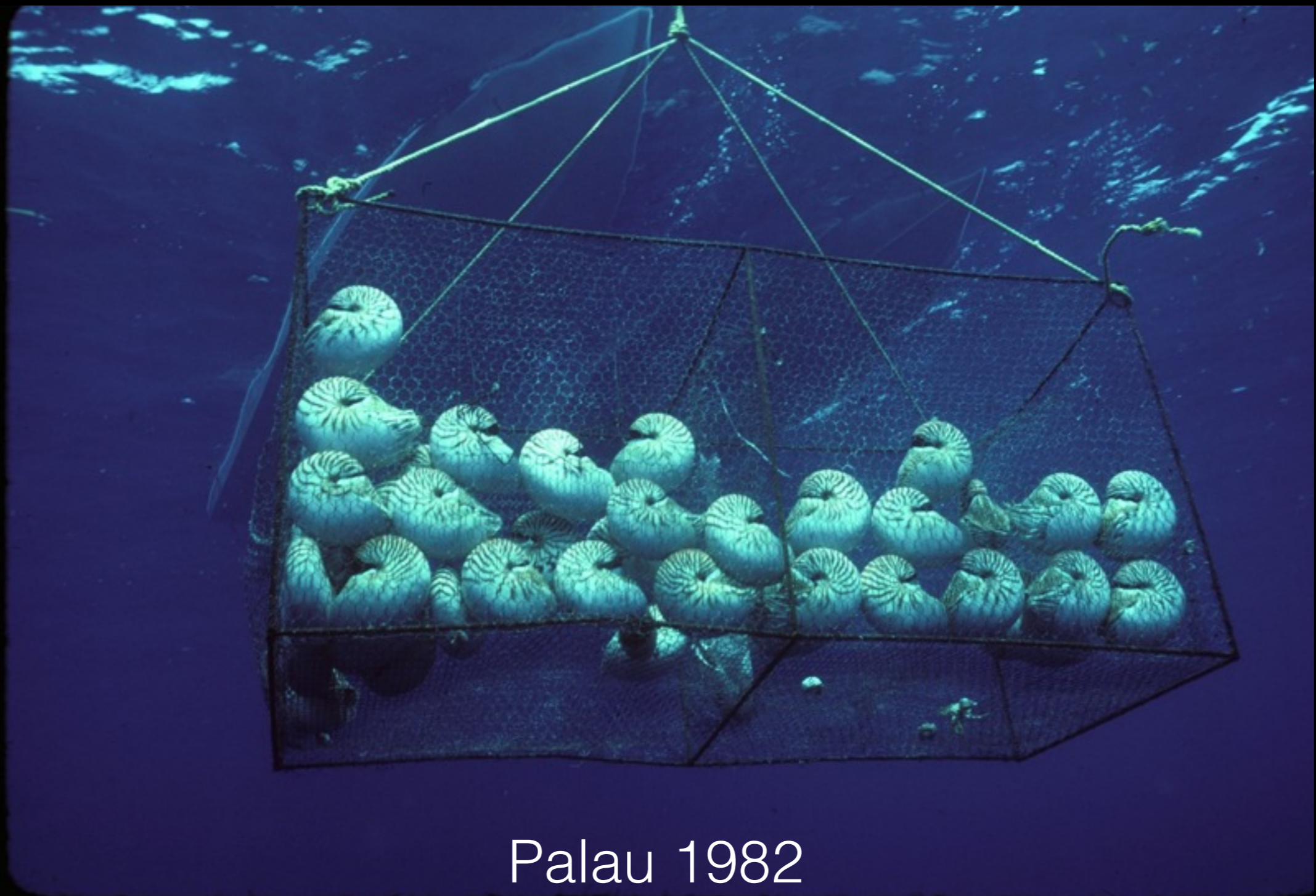
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Palau: 1982-1985 (?)
Bruce Saunders with assistant Mike Weekley from the Waikiki Aquarium



Palau 1982

An example of Saunders & Weekley's successful trapping efforts



Palau, Ngemelis
Bruce Saunders & Mike Weekley measuring, tagging & releasing *Nautilus*

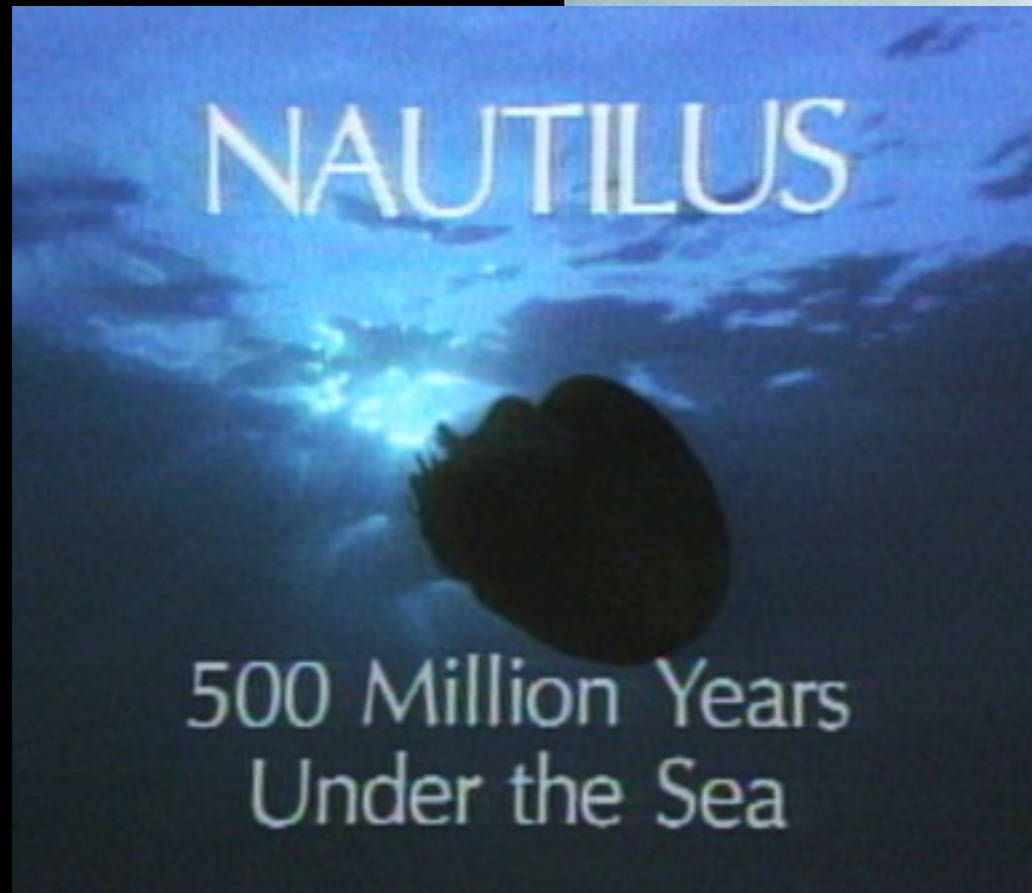


Palau, 1982

Mike deGruy, Paul & Gracie Atkins filming Bruce Saunders & Mike Weekley for Nautilus documentary for KHET Hawaii Public Television, and later for BBC. Funding provided in part by the Grass Foundation and Nautilus Sports Industries



Mike Weekley & Bruce Saunders during filming



Scene during filming: Mike deGruy on camera, Paul Atkins directing



Scene from documentary: “*Nautilus - 500 Million Years Under the Sea*”
Bruce Saunders & Mike Weekley



Scene from documentary: “*Nautilus - 500 Million Years Under the Sea*”
Peter Ward x-raying *Nautilus*



Palau, June 1982

Second transmitter study using neutral buoyancy sonic transmitters



Location at sea determined by compass in pre-GPS era.
This allowed us to plot the horizontal movements of *Nautilus*.

Telemetric Investigation of Vertical Migration of *Nautilus belauensis* in Palau¹

BRUCE A. CARLSON², JAMES N. MCKIBBEN³, AND MICHAEL V. DEGRUY⁴

ABSTRACT: Sonic transmitters coupled to depth-sensitive strain gauges and attached to shells of *Nautilus belauensis* in Palau, Western Caroline Islands, established net vertical movement between 85 and 467 m, and lateral movement of about 3 km over a period of 7 days and nights. Generally, the animals were found in deep water during daytime and moved to shallower water at night.

MOST GENERAL REFERENCES on the ecology and behavior of *Nautilus* indicate that these animals become active at night and move from deep to shallow water (Morton 1967, Barnes 1974, Yonge and Thompson 1976). This assumption can be traced to Arthur Willey, who conducted field research on *Nautilus* in the late 19th century: "I came to the conclusion in New Britain, which I afterwards confirmed in the Loyalty Islands, that the feeding-ground is not the breeding-ground of the *Nautilus*—or, in other words, that the nautilus migrates in shoals nocturnally from deeper into shallower water in quest of food. . . . In (the Loyalty Group) *Nautilus* migrates at night from deep water into as little as three fathoms" (Willey 1899:7–8). While Willey provided only sketchy details on how he arrived at this conclusion, his comments have been accepted as fact in virtually all subsequent literature on *Nautilus*.

Recently, Ward, Greenwald, and Magnier (1981) and Ward (1982) have noted that Willey's assumptions have never been confirmed by direct observation and suggested that perhaps *Nautilus* is better described as a slowly foraging organism of the deep nekto-benthos rather than an active animal covering wide depth ranges.

This study was undertaken in an attempt to

resolve this issue and to obtain data on the daily movements of individual *Nautilus* in its natural environment. Due to the depths at which *Nautilus* occurs, 50–260 m (Saunders and Wehman 1977), direct observation of this organism is impractical. The approach used here was to utilize sonic transmitters to track the movements of the *Nautilus*. We believe this is the first time this technique has been used successfully on any marine invertebrate.

MATERIALS AND METHODS

Nautilus belauensis (Saunders 1981a) was trapped along fringing reefs in Palau using baffle-type fish traps suspended along the reef face for 1–3 days. The animals used in this research were adult males (ca. 190 mm shell diameter). They were collected at approximately 200–300 m depth on the afternoon of 19 June 1982 by Bruce Saunders who inscribed a number on the shell of each animal (#3028 and #3040) as part of an ongoing tag-recapture study of *Nautilus* in Palau. The animals were trapped seaward of the southeast reef face of Augulpelu Reef and were maintained in chilled seawater (18°C) on board the boat until tagged. After the transmitters were attached, the animals were released about 2 km west of their capture site (Figure 1).

The two transmitters used in this study were designed to provide depth information and to indicate lateral movement of the *Nautilus*. Design specifications were determined after testing a prototype model on *Nautilus* in Palau

¹ Manuscript accepted 16 April 1984.

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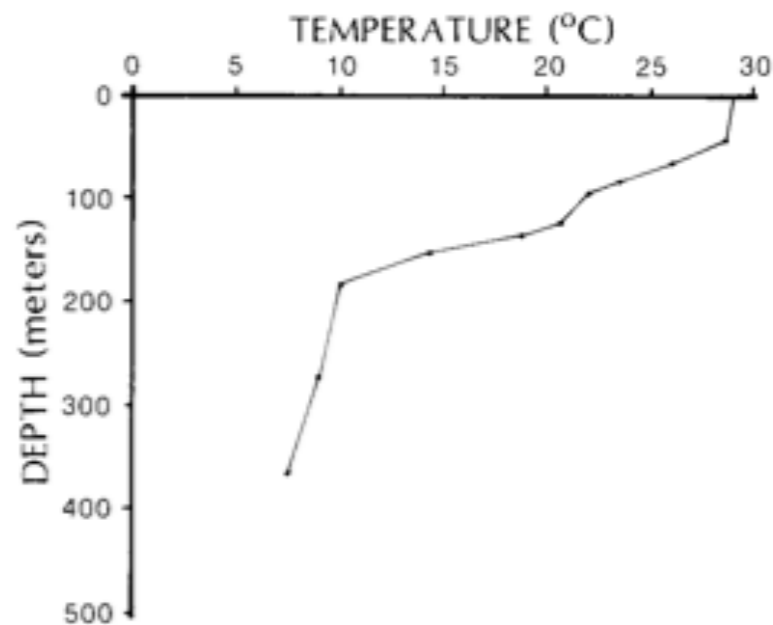
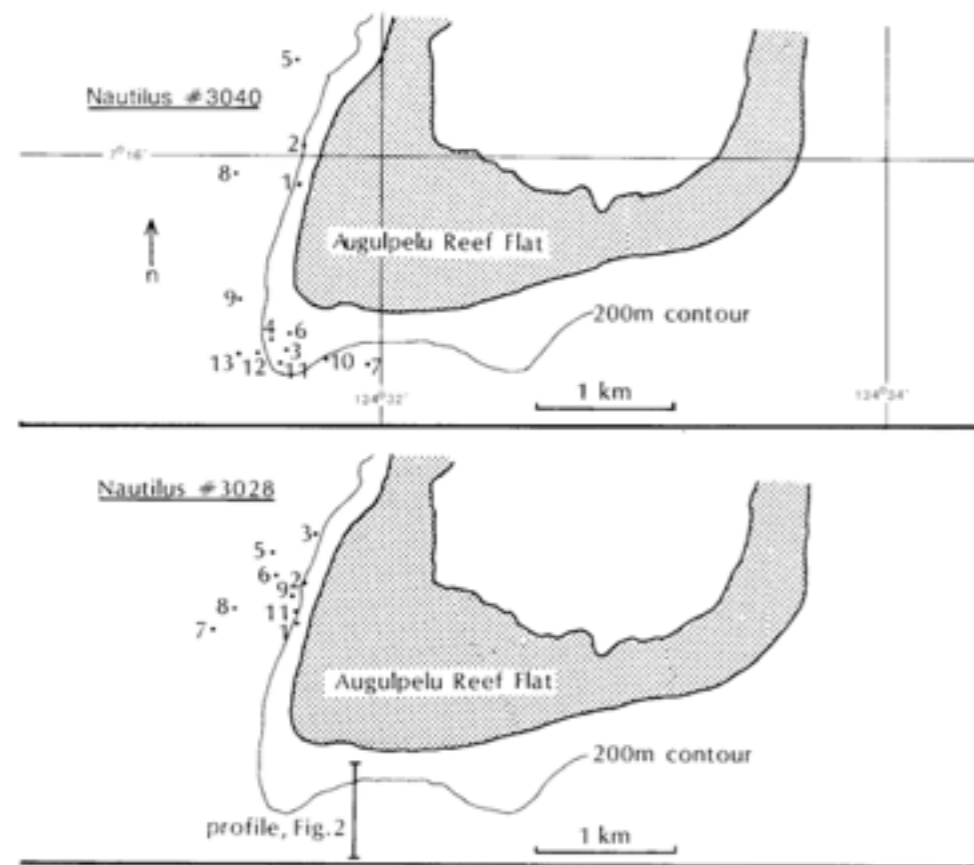


FIGURE 3. Temperature profile at Augupelu Reef, Palau.



FIGURE 4. Daily vertical movements of Nautilus #3040, 19-26 June 1982, at Augupelu Reef, Palau.

Due to rough sea conditions, a complete tracking was impossible but sufficient data were gathered to demonstrate a daily migration pattern among Palau *Nautilus*



1983, Palau

Repeat expedition with Peter Ward to track *Nautilus* with transmitters



Peter Ward during Palau *Nautilus* tracking research

Remote telemetry of daily vertical and horizontal movement of *Nautilus* in Palau

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Vertical depth migrations, by the chambered cephalopod *Nautilus* when moving into shallower waters at night, were first documented by Wiley¹. Although unsupported by quantitative data, this observation strongly influenced the interpretation of the mode of life of *Nautilus* and of the palaeoecology of fossil chambered cephalopods²⁻⁴. To determine whether these migrations do occur, we mounted ultrasonic transmitters on four *Nautilus belauensis* in Palau. The transmitters contained a strain-gauge depth sensor that caused the transmitters to emit sonic pulses at intervals that varied with depth, so that geographical position and depth could be ascertained. Our results indicate that at least in this population or geographical area, vertical depth changes of up to 200 m per day are common. Although too soon to make generalizations about other populations of *Nautilus* in the Pacific, it has been suggested that the morphological position of the siphuncle within the phragmocone of the chambered shell would increase the efficiency of vertical migrations in *Nautilus*, if such migrations were found to occur^{5,6}. As similar siphuncle configurations are common in most post-Triassic nautiloids, and some ammonoids^{6,7}, it could be that vertical migration was common in many fossil forms as well.

The sonic transmitters were first calibrated in pressure tanks, and by submergence in the sea to known depths. The devices were designed to emit at different frequencies (between 38 and 41 kHz), allowing two *Nautilus* to be tracked simultaneously, and were filled with non-compressible glass microballoons to make the transmitters neutrally buoyant in seawater. The batteries gave the transmitters a life of 7-14 days, and a horizontal range of ~2 km. The transmitters sat in moulded rubber saddles that allowed them to be mounted on the tops of the shells of large, mature *Nautilus* (two males and two females). The *Nautilus* were captured at 200 m in baited traps, and after being fitted with the transmitters, immediately returned to the sea and released by divers at a depth of 70 m. All four *Nautilus* quickly descended to about 200 m, at which point the periods of observation were started. The *Nautilus* were tracked using Dukane hydrophones.

The four *Nautilus* monitored (termed Yellow, Green, Blue and Red, based on colour coding of the transmitters) were tracked for periods of between 2 and 10 days (Figs 1, 2) during June-July 1983. Completeness of tracking depended entirely on weather conditions. Conditions were nearly ideal during the tracking of Yellow, allowing continuous daytime and nighttime work, but much less favourable for Green, Blue and Red, which were tracked mainly during daytime hours. All four animals showed significantly deeper mean daytime than nighttime depths (Table 1). Yellow, Red and Green showed daily ascents, occurring between 1600 and 2000, and descents between 0400 and 0700. (During our observation period (June-July 1983) sunset occurred at 1815 and sunrise at 0545.) Yellow was extremely regular in its diurnal movements. Blue was more irregular, and on three occasions (8, 10 and 13 October) showed evening descent rather than ascent. Because tracking was incomplete we do not know whether this animal ascended later on these evenings.

The tracking data indicate no daily rest periods. Although

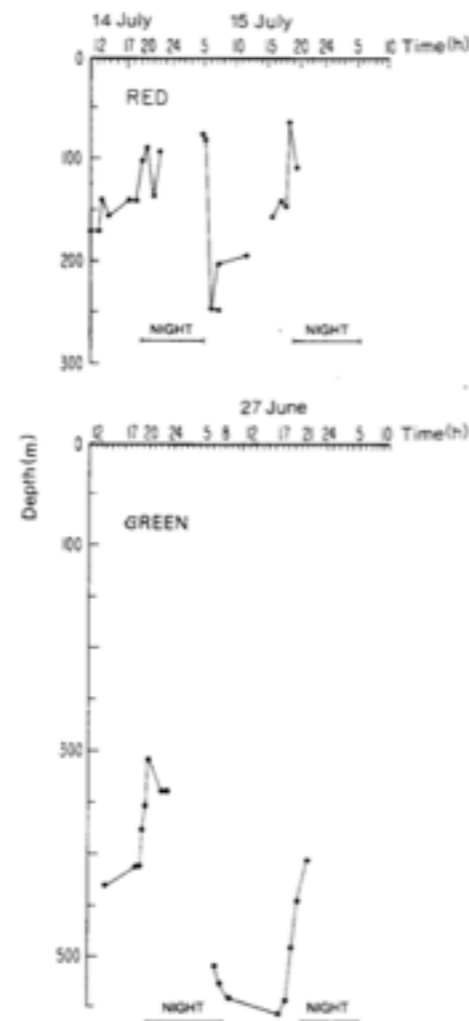
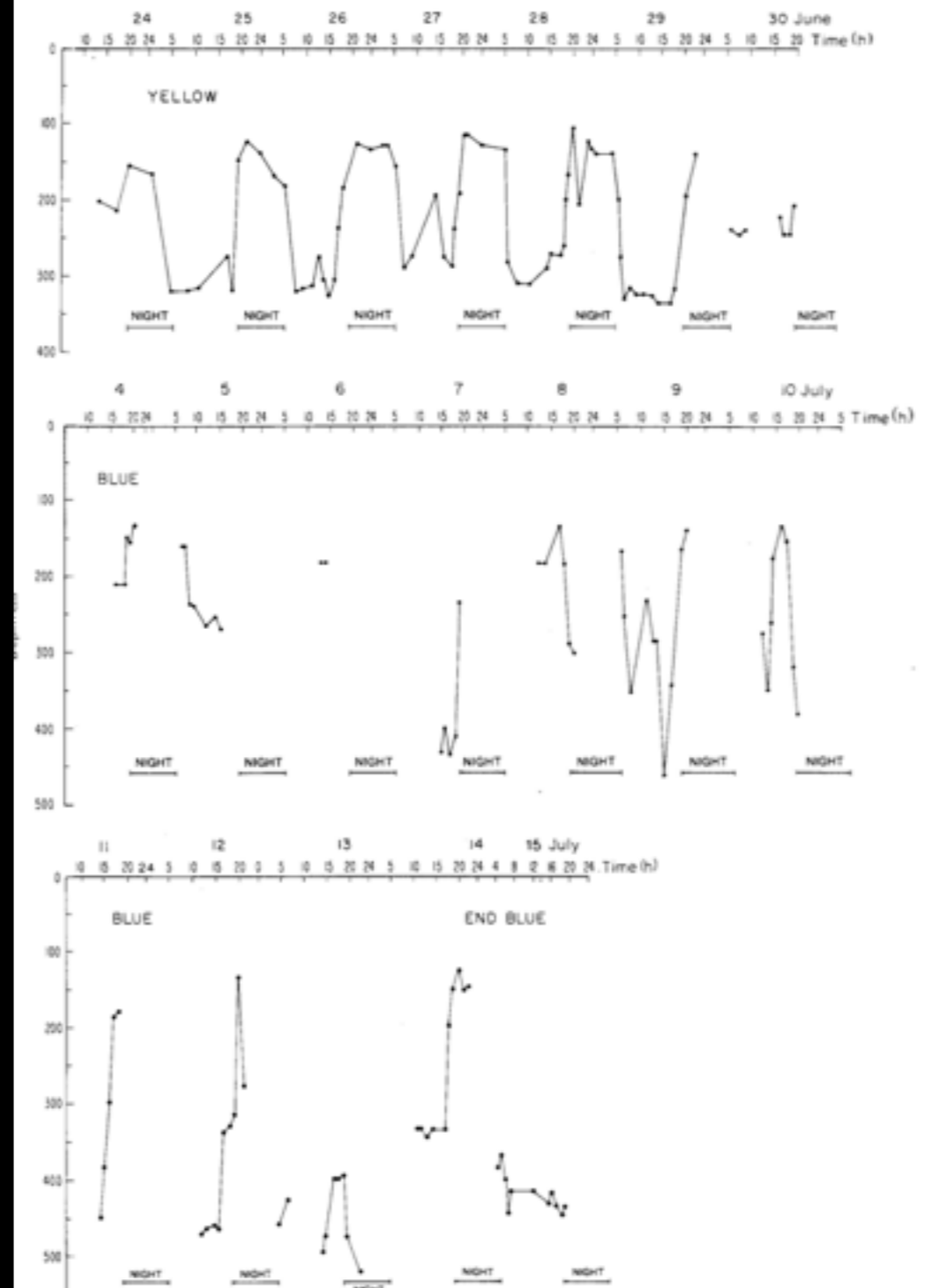


Fig. 1 Vertical movement of two *Nautilus*: Red, followed during 14-15 July 1983, and Green, followed during 27-28 June 1983.

dusk, other vertical movements also occurred during day and night-time hours. We never observed any *Nautilus* spending longer than a few hours at the same depth; our data suggest nearly constant activity.

All four *Nautilus* showed substantial horizontal as well as vertical movement. One (Yellow) showed a somewhat regular pattern of movement around the south-west corner of Angulpelu Reef; each daylight period it moved into deeper water on the south side of the reef, while at night it moved around the point, into the large bay defined by Angulpelu and Ngadarak reefs, a distance of ~1 km. The other three *Nautilus* showed a different pattern. After being released near the point of Angulpelu reef, Green, Blue and Red began a daily southwestern movement along the 200 m contour of the bay. Superimposed on this southwestern horizontal movement was vertical movement, which was accomplished by inshore and offshore motion. Because of the steepness of the Palauan reefs, very short horizontal distances resulted in large vertical displacements. The Blue animal, followed for the longest period, travelled a total of 16 km along the reef front during the 10-day observation period. Horizontal movements of a similar magnitude have been observed previously for longer time periods in this population of *Nautilus*⁸.

The depths at which *Nautilus* were found, as computed from the ultrasonic emissions, were compared with the bottom depth recorded nine times using a fathometer. The two depths differed

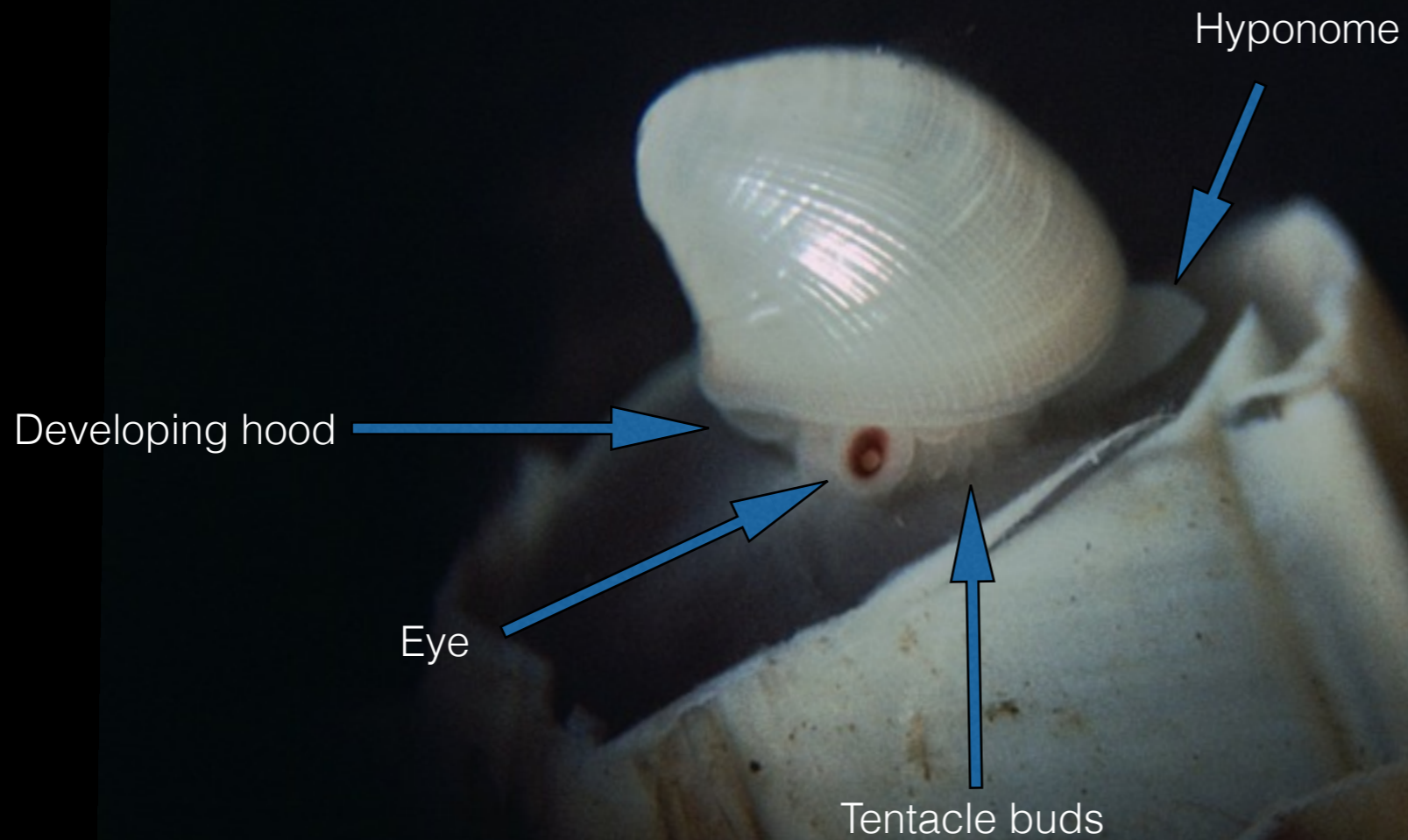


The 1983 study yielded an even better data set demonstrating vertical migration



Nautilus belauensis mating

Funding from the Grass Foundation allowed us to continue work to breed *Nautilus*



Waikiki Aquarium: March 1985

This was the first *Nautilus* embryo known to science



Palau: John Arnold & Marj Awai, 1986
John Arnold joined us to describe the first *Nautilus* embryos
Marj Awai managed the *Nautilus* incubator aquariums



Early *Nautilus* embryos

Photos by John Arnold
University of Hawaii

LIVING NAUTILUS EMBRYOS: IN OVO MOVEMENTS.

SOME COMPARATIVE ASPECTS

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ABSTRACT

In the living *Nautilus* embryo there are four distinctive movements: First there was rhythmic contraction of the retractor muscles and associated musculature which is undoubtedly a respiratory action. Secondly, there was a quick contraction which pulled the whole embryo down against the external yolk and probably is a protective retraction similar to that seen in the adult. Thirdly, there was a sudden circumferential contraction of a band of large muscle cells which formed a deep indentation and corresponding large bulge directly below the embryo. This may promote circulation of the yolk and blood in the yolk sac. And fourth, the whole embryo slowly rotated inside the inner egg capsule. This possibly was caused by ciliary action. The possible functions of these various movements is discussed and compared with similar movements in other species of cephalopod embryos. The possible significance of *Octopus* embryo inversion is discussed.

Reprint Series
4 April 1986, Volume 232, pp. 73-76

SCIENCE

Living *Nautilus* Embryos: Preliminary Observations

JOHN M. ARNOLD AND BRUCE A. CARLSON



Pre-hatching *Nautilus* protrude from egg capsule allowing them to grow to larger size before hatching while still providing protection as soft parts remain within egg capsule



Newly hatched *Nautilus belauensis*



Newly hatched *Nautilus belauensis*
Tom Kelly Photo, Waikiki Aquarium



Waikiki Aquarium: 1990

First U.S. hatchling *Nautilus belauensis*

Note the open umbilicus

(freeze-frame from super-8 movie)

Japan: December 27, 1988 - first hatchling

Waikiki Aquarium freely shared information with Japanese colleagues on how to incubate *Nautilus* eggs and they succeeded in hatching the first *Nautilus*



Nautilus feeds almost immediately after hatching
Tom Kelly photo, Waikiki Aquarium



Nautilus belauensis, 250 days

To our amazement, *Nautilus* embryos do not die after the egg capsule is opened thus allowing us to videotape a developmental sequence from 250 - 272 days. This effort should be extended to include the entire developmental sequence. (Freeze-frame from video)

Hatching and Early Growth of *Nautilus belauensis* and Implications on the Distribution of the Genus *Nautilus*

BRUCE A. CARLSON¹, MARJORIE L. AWAI¹, AND JOHN M. ARNOLD²

Abstract. Egg laying by captive *Nautilus* spp. has been reported by several public aquariums and marine laboratories, but until recently all efforts to hatch the eggs have failed. Since the adults most commonly occur at great depths, cold temperature and high pressure were believed necessary for development to proceed. Recent successful hatchings at the Kagoshima Aquarium in Japan, and at the Waikiki Aquarium in Hawaii, indicate that *Nautilus* eggs are able to develop in relatively warm, shallow water, with incubation lasting up to one year. While adult *Nautilus* can tolerate very cold temperatures, the apparent necessity of warm water for successful embryonic development and hatching of eggs may limit its distribution to tropical latitudes.

Introduction

In 1895, Arthur Willey traveled to the tropical west Pacific to pursue what has been called the "Holy Grail of invertebrate embryology: the developmental sequence of nautilus" (Ward 1988). Willey spent three years in New Britain, and New Caledonia trapping *Nautilus* and succeeded on December 5, 1896 in obtaining *Nautilus* eggs from captive animals held in traps. Unfortunately, during the following weeks when the eggs were examined, he found that all were infertile. He tried a variety of methods to incubate the eggs including "pairing off the nautili in some, associating them in companies of others, manufacturing dark recesses in sackcloth,

all to no purpose. The eggs were all infertile and often simply consisted of the empty capsules without any vitellus inside" (Willey 1902).

Interest in the embryology of *Nautilus* was rekindled in the latter half of this century when it was discovered that *Nautilus* survives well in captivity. The Noumea Aquarium was the first to maintain *N. macromphalus* in an aquarium in 1958. In 1976 the Yomiuriland Aquarium in Japan, and the Waikiki Aquarium in Hawaii were the next to successfully maintain living *Nautilus*.

In 1984, the Waikiki Aquarium sent a questionnaire to aquariums world-wide maintaining *Nautilus*. Seven of 14 responding aquariums reported obtaining *Nautilus* eggs, but all were infertile (Carlson 1987). Catala (1986) of the Noumea Aquarium, concluded that, because *Nautilus* inhabits deep water, its eggs probably require cold temperature and high pressure to develop. The failure to discover *Nautilus* eggs in the field suggested that the eggs are laid in deep water below depths that divers can safely go. However, the question of "how deep?" was crucial to finally obtaining fertile eggs.

The first *Nautilus* embryos were finally obtained in 1985 at the Waikiki Aquarium but under conditions which were the opposite of those suggested by Catala (Arnold and Carlson 1986). These eggs were part of a batch which had been maintained in a relatively warm incubator tank (about 21°C to 24°C). They were allowed to develop for four months unlike all other eggs which were examined only a few weeks after being produced. A total of 14 embryos was obtained by this method, and they are now the focus of a detailed embryological description—the culmination of the quest begun 90 years earlier by Arthur Willey. The small size of the embryos after four months of development led us to conclude that incubation would require up to 12 months (Carlson 1985).

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² Pacific Biomedical Research Center, Snyder Hall 209A, University of Hawaii, Honolulu, Hawaii, 96822. Business telephone: (808) 923-9741 Fax number: (808) 923-1771

To Bruce,
with sincere
thanks,
Neil

Early life history of *Nautilus*: evidence from isotopic analyses of aquarium-reared specimens

Neil H. Landman, J. Kirk Cochran, Danny M. Rye, Kazushige Tanabe, and John M. Arnold

Abstract.—Specimens of *Nautilus* species caught in the wild show a marked increase in oxygen isotopic composition between embryonic and postembryonic septa. The significance of this increase in terms of the early life history of *Nautilus* has been unclear. To help explain this pattern, we analyzed the isotopic composition of the septa of three specimens of *Nautilus belauensis* raised in aquariums under controlled temperature conditions. Our results indicate that both embryonic and postembryonic septa are secreted with the same temperature-dependent fractionation of aragonite relative to water as that of other aragonite-secreting molluscs (Grossman and Ku 1986). The $\delta^{18}\text{O}$ values of the septa thus provide a reliable means of determining the water temperature in which the septa form. Calculated temperatures based on oxygen isotopic data from specimens caught in the wild reveal that embryonic development occurs at 22°C–24°C corresponding to a depth of 100–200 m depending on the location. The increase in $\delta^{18}\text{O}$ in postembryonic septa reflects a migration into colder, deeper water after hatching. In Cretaceous nautilids, a systematic shift in $\delta^{18}\text{O}$ is not present, indicating that these animals probably did not change their habitat after hatching. This is consistent with the likelihood that they lived in shallower environments than that of modern *Nautilus*.

By recording daily temperatures throughout embryonic development at Waikiki Aquarium & Kamoike Aquarium, Landman et al. could finally and conclusively validate that oxygen isotope ratios in *Nautilus* shells are indeed a proxy for temperature during development. **There is no fractionation of isotopes through the egg membrane.** Embryos in the wild develop in shallow, relatively warm water (ca. 100–200m & 22–24°C) then move to deeper colder water after hatching as first postulated by Eichler & Ristedt in 1966. This coincides with our Aquarium research that embryos will only develop in warmer temperatures. Embryos may take a year to hatch.

方法2 卵と幼体の管理

Method 2: Management of eggs & hatched juveniles

・孵化専用水槽(0.77×0.66×0.51m) Hatching tank ca. 65 gallons

水温 22.0—25.0°C Water temp.

・孵化日数 オウムガイ 201—362日 N. pompilius

Days to hatching オオベソオウムガイ 255—385日 N. macromphalus

・幼体の餌料

無頭エビとキビナゴ/週に2回

Food for juveniles:
shrimp heads & silverstripe round herring
twice per week



幼体の給餌風景

方法3 Method 3

幼体の Juveniles

・孵化率 Hatching rate

・生存率 Survival rate

・殻径(長径)の計測

・雌雄判別 Sex determination

↓
比較

Compare



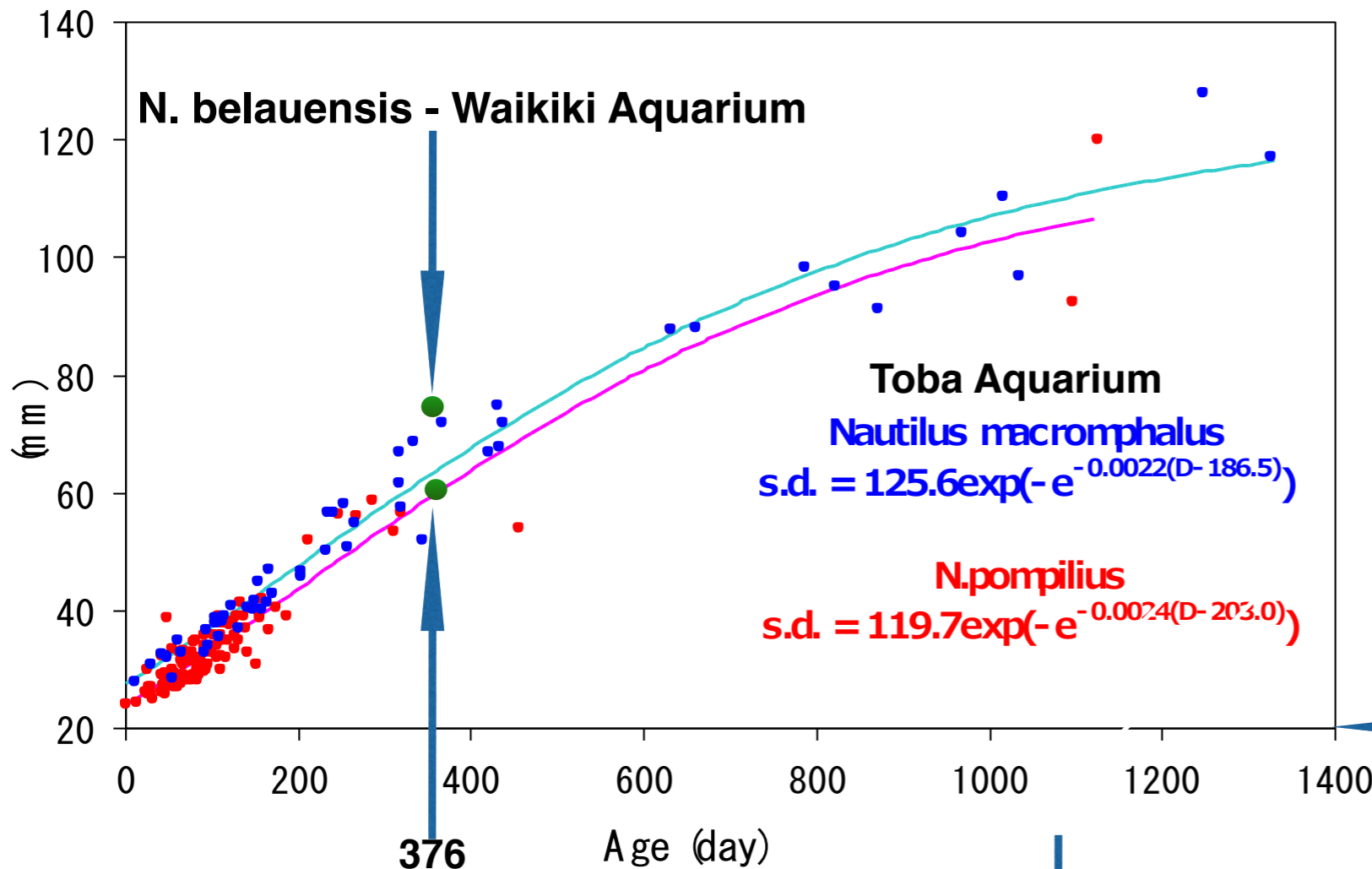
Measuring shell length



Toba Aquarium: 2009

Powerpoint from Toba Aquarium discussing their hatching system and success

Growth curve Gompertz



Toba Aquarium growth data

Record:

1689 days (4.6 years) = 13cm

only 11 out of 220 hatchlings lived to 1000 days

Aquarium Growth Rates

Under Aquarium conditions, hatchlings grow rapidly at first then the growth rate plateaus similar to many other marine organisms. But whether these growth rates are similar to those in the wild is open to speculation. Aquarium animals may grow more quickly in shallow aquariums with virtually no hydrostatic pressure and plenty of food.

Hatching and Early Growth of *Nautilus belauensis*

591

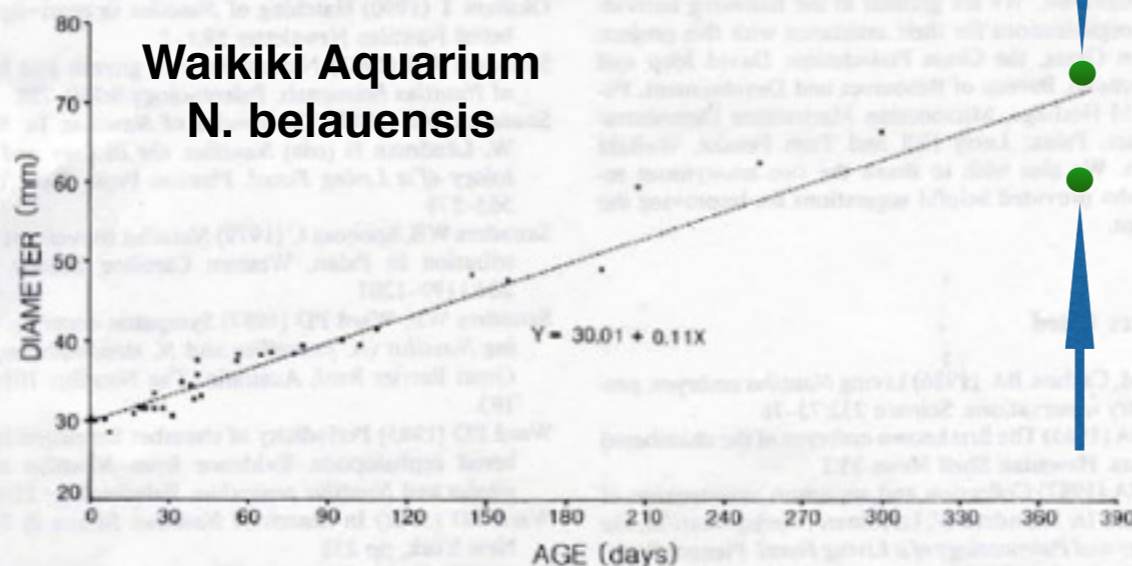


Fig. 1. Increase in maximum shell diameter of *Nautilus belauensis* hatchlings at the Waikiki Aquarium. Data from ten

Toba Aquarium's chambered nautilus breaks record for oldest in captivity

🕒 February 27, 2014

🐦 Tweet 5

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By NAONORI NAKAMURA/ Staff Writer

TOBA, Mie Prefecture--Known as "living fossils" dating back about 500 million years, a female chambered nautilus in the Toba Aquarium has become the world's oldest species raised in captivity, living 1,691 days as of Feb. 23, aquarium officials said.

The previous record was 1,689 days, by a male chambered nautilus, also raised in the aquarium.

The officials said it is extremely difficult for the cephalopod that were bred in captivity to survive for such a long time, although the species in the wild typically live more than 10 years.

The female chambered nautilus' shell measures about 13 centimeters in diameter. It was hatched on July 10, 2009.

Apart from the Toba Aquarium, the Lagoons Aquarium in New Caledonia and the Wikiki Aquarium in Hawaii raise the rare species.

But the Toba Aquarium is the only facility that has succeeded in rearing the cephalopod for 1,000 days or more.

Of about 220 species hatched at the aquarium, only 11 made it to 1,000 days.

The chambered nautilus is a cousin of the octopus and the squid. It appeared in ancient seas even before the ammonite, which is now extinct.

The mollusk lives at depths of 100-500 meters in coral reefs in the South Pacific and elsewhere.

Some of those in the wild have shells as wide as 20 cm, but not its peers in captivity because they tend to mature early.

Toba Aquarium is raising 20 chambered nautiluses.

By NAONORI NAKAMURA/ Staff Writer

chambered nautilus nautilus world record Toba Aquarium
aquarium Mie



The world's longest living chambered nautilus in captivity (Provided by the Toba Aquarium)



Presenter's Note: Observe that all aquarium raised animals display unusual coloration and deformities (black growth lines)





Brian D. Greene

May 17

Found this little guy under a ledge at 117m (387ft) on the west side (South China Sea) of Lubang Island, Philippines. Too bad it wasn't still alive. Made a 100m night dive this evening in hopes of encountering live Nautilus as they make their way up slope to shallow(er) water, but no such luck. With Richard Pyle, Luiz Rocha and Elliott Jessup. — at Lubang Island, Occidental Mindoro.



Discussion on eggs:



May 17, 2014: Brian Greene, working with deep-divers from the California Academy of Sciences discovered this juvenile *Nautilus* shell at 117m. In 2015 they will return and will continue searching for *Nautilus* eggs and hatchlings.



Solomon Islands

We set one trap in the Solomons (New Georgia region) hoping to find *Allonautilus scrobiculatus*. We had acquired shells there on earlier visits. Our trap yielded only typical *Nautilus pompilius*.





Nautilus shells are critical to Solomons wood carvers for inlay. They use only drift shells. Our trapped animals were the first they had ever seen alive.



E-mail: May 31, 2014

Want you to get this- will do some more research, but asked Ronald's dad- one of the oldest carvers in Chea this morning and he confirmed that it was only "Drifters" that they harvest here- there is no harvesting of any live (Nautilus) shells.

Thank you a million for thinking of this one- it would severely impact the carvers and a main source of livelihood for the villagers in Western Province, which would, in turn, I'm sure, turn them to harvesting more and more of natural resources- namely, fish and other sea products- turtles, shells, etc. , and timber. So totally protecting them internationally might have the effect of driving other resources to the edge.

Lisa Choquette
Solomon Dive Adventures
Chea (Vangunu Island)
New Georgia, Solomon Islands

AZA Survey of U.S. Aquariums Displaying *Nautilus*
(George Parsons, Shedd Aquarium)
May 2014

- **52/102 Institutions replied**
- **13/52 (25%) exhibit *Nautilus***
- **Total # presently in all exhibits = 94**
- **Origin:**
 - **50% Philippines**
 - **7% Indonesia**
 - **43% unknown**
- **# imported over the last 5 years:**
 - **203**
- **Survival rate in aquariums:**
 - **0-1 years 33.3%**
 - **1-2 years 6.7%**
 - **2-3 years 20.0%**
 - **3-5 years 20.0%**
 - **>5 years 20.0%**

“Quality Marine” Los Angeles Aquarium Fish Importer - Conference Call May 28, 2014

- Nautilus origins: Cebu & upper Manila, Luzon
- How many imported: average 5, maximum 30/year
- Who buys them: 70% to public aquariums & labs
- (e.g., Smithsonian, Ripleys, Woods Hole, Russia (?))
- Any hatchlings: not aware of any
- Note: QM peruses wholesale lists of many competitors, none list Nautilus - it is a “special order” item only

Nautilus

i saw a nautilus for sale at my LFS and was wondering are they good additions to a FOWLR?

how difficult are they to keep?

diet?

aggressive?

i just wanted as much information as possible before making any commitments

thanks,

DO NOT DO IT!!!! They are horrible candidates for a fowlr. They require a large, tall, chilled, calm species tank. Very few people keep or are able to keep them.

Best left for the ocean or public aquariums. They are interesting to look at for awhile, but don't move much and need cool water and so on (as stated above). Few people have had any real success. Best to keep them by themselves. By the time they reach the hobbyist, they are pretty "beaten up" and just waste away quickly.

It is my suspicion that within a short time you would either have a dead nautilus or a nautilus only with live rock tank as nautili eat fish.

I would advise agist keeping as we had a professor that maintained a tank of them when I was in grad school and after the first hour of "WOW, these are neat!!!" they were quite boring to watch them float around the tank being moved by the currents of the filtration system.

Unless you have a public aquarium with a 8000 gal tank in your house, do not buy a Nautilus. It is sad that this animal is even for sale, it is doomed to starving to death and all the while trying to escape its small enclosure by banging against the sides. I would let the LFS know the facts regarding this animals husbandry and not give this LFS another dollor of my money. Research.

Are for the very advance hobbyist. Keeping one for a 100 days is hardly a success. And yes they need a vertical tank at least 150 gal for one speciman. They also need a chiller and they must remain in the dark, otherwise they will go blind (not that they can only see in the dark). The Nautilus are slowly becoming endangered and to take them from the deep oceans so someone can have a trophy pet is an impulse buy at the expense of the Nautilus. I imagine most have what you stated is hear say. Please provide valid scientifc information and pics, before you suggest that anyone can keep a Nautilus. L 8 2 Rise
<http://www.thecephalopodpage.org/Npompil.php>

Hobbyists - These are responses from peer-level hobbyists when asked about keeping *Nautilus*. (Names and source removed. "LFS" = local fish store)

It never ceases to amaze me at just how little people understand and appreciate what a precarious state our oceans are in now, so to bring you back to earth what you did not include in the previous commentary was that its not just collection practices for the shell hoarders and the aquarium trade it is the very acidification of the ocean globally that threatens all calciferous organisms coral, clams, snails and yes even the nautilus. I question the language you used in your responses when you stated that fellow hobbyists should "go for it" after all this isn't dating advice as in "go for it, call the girl"? This sale represents contributing to the demise of an all ready threatened relic of a by gone era. It is unrealistic to speculate that the hobbieist will successfully propagate nautili in the home setting as most individuals whom have propagated less demanding cephalopods over the last several years have had extensive capital dumped with dismal returns. The purpose of this hobby is not just to play Jacques Cousteau in a bowl, it is in fact to carry the message that he conveyed to many of us, that the sea despite it's rugged, infinite exterior is in truth quite fragile.

It does look like Naut populations are declining - at least locally. In places where they used to be collected easily, they are no longer collected easily.

IMO, Nauts are not an animal that should be tried on a lark or whim. They have specialized needs and are not the most interesting animals most of the time, so you really need to be interested in them in particular if you want to keep them. I wish LFS would only special order them instead of trying to stock them for impulse buys.

There is plenty of misinformation out there regarding nauts, both about how hard they are to keep and how easy they are to keep. Please before thinking about Nauts (or any ceph) do some real research. TONMO.com is a good place to start, as is the TFH cephalopod issue from a year or two ago, and Cephalopods: Octopuses and Cuttlefish for the Home Aquarium (<http://www.amazon.com/Cephalopods-Qc.../dp/0793806585>)

I am not sure why someone would want to keep something that advanced. It really has no business being in a home aquarium.

Ok, now this thread is getting out of hand. Yes, nautilus are very hard to keep, yes, they are EXTREMELY boring, but no, they need not be left only to the public aquariums nor enormous aquariums, nor are they likely subjects to starvation. An ideal size for these would be a tank that's something like 2*2*4 feet tall. However they can be kept in different size tanks, and even in standard tanks that aren't extra tall, though I wouldn't suggest it. You will need the tank chilled down to a pretty low temperature, and I wouldn't suggest fish or any other tank mates for that matter. Their eyes can only "see" night and day. You should easily be able to get them eating live foods if you meet all of the above requirements, and they should also go onto frozen pretty well. Many people/places that keep nautilus will end up with eggs at some point, however they take a very long time to hatch (can't actually remember how long), and once they do, so far, no one has raised them to maturity, though I think some have gotten them to about the 100 day mark (this may be incorrect, can't remember). If you are dedicated and do your homework, you can do it, however I would because, as stated, they're boring, hard to keep, etc.



Freeze-frame shot of resting *Nautilus belauensis*
taken during manned submersible dive.

Video courtesy of Patrick Colin, Coral Reef Research Foundation, Palau